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DESIGN OF CONTROL AND MONITORING SYSTEM FOR BOILER WASTEWATER TREATMENT PROCESS USING PROGRAMMABLE LOGIC CONTROLLER AND HMI (HUMAN MACHINE INTERFACE)

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Abstract -- *Wastewater Treatment Plant (WWTP) is one of the infrastructures and systems in the manufacturing industry. This system serves to treat wastewater coming from boiler machines, which are used to produce steam to support the tire and tube production process of manufacturing companies, which are the object of our research. Wastewater from this boiler machine is alkaline and contains solids that are harmful to the ecosystem and the environment, so it needs to be processed so that wastewater can be discharged into drains. The process is not by following the standards; it can affect the quality of the process water so that water that is discharged into drains or water bodies violates government regulations. In this case, the pH standard of water is in a neutral state whose values are between 6 and 9 and is clear in color. Therefore, we conducted research that is designing a system to control and monitor the process at the wastewater treatment plant automatically. The design of this control system is done by adding sensors and actuators that are connected to the modular PLC that is the control system. This system is also designed to be connected to a PC (Personal Computer) as a monitoring system so that the process can be monitored continuously. Display interface created using HMI (Human Machine Interface) software. This is because many features that allow for a more attractive appearance. With this system, it can be sure that the boiler wastewater treatment process is more consistent and efficient in maintaining pH standards, and the process is monitored in real-time.*

Keywords: *Wastewater Treatment Plant; Boiler Machine; PLC; HMI (Human Machine Interface)*

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INTRODUCTION

This research was conducted at an automotive manufacturing company that manufactures motor vehicle tires. In this company, the management of the Wastewater Treatment Plant is under the auspices of the Department of Power and Utility. Wastewater treatment includes the treatment of boiler engine blowdown results that will be chemically processed using chemical solutions. The results of the waste treatment process are water with a neutral pH and free of hazardous and toxic materials, and sludge that is ready to be disposed of in a hazardous and toxic materials disposal site.

Along with the Government regulation on Wastewater Quality Standard, it is explained that the wastewater that is allowed to be discharged directly into the river flow is class 1. That is, it must meet the parameters by following government regulations, one of which is the pH is in the value of 6.0 - 9.0, dissolved solid content <1500 ppm, and must be in a clear, mud-free state.

Furthermore, we designed an automatic process control system using a PLC that can control and monitor the course of the wastewater treatment process. In this case, we designed an interface that can monitor parameters and field conditions without having to be in the field directly. Systematically, this research implements various devices, sensors, controllers, Human Machine Interfaces, all of which are oriented towards the development of the manufacturing industry 4.0.

Several studies and researches related to the use of PLCs for various control systems, including: [1, 2, 3, 4, 5, 6, 7, 8, 9] have been published. Also, we have conducted various studies related to the use of PLCs as a control system and HMI, for various systems and machinery, especially in the area of manufacturing and automotive industries [10, 11, 12, 13, 14, 15, 16, 17, 18, 19].

Furthermore, this research is focused on the design of a system that can control the overall boiler wastewater treatment process using PLC as a programmed control. Also, this study conducted an HMI Wonderware Intouch interface that is used to monitor the processing of waste. This design can provide significant benefits because the wastewater treatment process can operate automatically, reduce data recording errors, monitor systems in real-time and remotely, and ensure that the wastewater produced is by following the desired standards.

METHOD

Production Process of Tires and Tires

The process of making an outer tire (tire) includes the process of mixing raw materials to be processed into rubber sheets (compound), coating nylon thread with the compound so that it forms a topping cord sheet which is then cut into a ply cord, cutting compound according to a certain size that produces a tread, coating of wire with the compound so that it becomes a bead wire. Furthermore, the ply cord, tread, and bead wire will be combined and become a green tire, and then a green tire will be given a special liquid to avoid adhesions in the maturation process. After that, the green tire will be given an air hole so that during the curing process, the air collected in the green tire can be removed. The final step in the process of making an outer tire is the curing process so that it becomes an outer tire.

The making of an inner tube has with mixing the raw material so that it becomes a compound. The finished compound will be filtered from foreign material. Furthermore, the filtered compound will be processed to form a tube forming tube then cut to a certain length. After cutting, the tubing will be fitted with a valve and then connected to form a green tube. Furthermore, the green tube will enter the curing process and become an outer tire.

Most of the tire processing uses heat energy from steam, especially in the cooking process, so that machines are used that can produce steam in large quantities with high pressure. The machine used to produce steam is a boiler engine that works by heating water at high temperatures to become steam. However, not all the water will evaporate, the remaining water will be discharged to the wastewater treatment body, and the boiler machine will be filled with clean water.

Wastewater Treatment Plant

The Wastewater Treatment Plant (WWTP) is a system infrastructure designed to remove biological or chemical waste from water to enable the water to be used in other activities or properly discharged into waterways without damaging existing ecosystems.

The function of the wastewater treatment plant is:

- Treat domestic or industrial wastewater, so that the water can be reused according to their individual needs.
- So, that the wastewater that will be flowed into the river is not polluted.
- So, that the biota in the river does not die.

Industrial wastewater treatment that is processed in WWTP includes a decrease in the pH level of water from a boiler machine blowdown that is generally alkaline (pH 10-12) to neutral or according to specified standards (pH 6-9), reduction in the conductivity level, and separation of water by mud which is a hazardous and toxic material. This includes chemical and physical processes to remove chemical contaminants. The aim is to produce a water flow that is by following predetermined standards.

Work Process Flowchart

The boiler wastewater treatment plant consists of treatment units and a tool for treating wastewater. Wastewater treatment units consist of equalization units, coagulation units, flocculation units, clarifier units, and final tank units. Figure 1 shows the work process flowchart.

Problem Analysis

Wastewater, which is a source of wastewater from boiler activities, comes from a boiler engine blowdown. The wastewater impurity component of the steam boiler discharge comes from chemicals used for mixing water with the aim that the boiler pipes are resistant to scaling or pipe crust or rust prevention on boiler pipes. The chemicals are usually made from Zinc phosphate, which has alkaline characteristics so that the water in the boiler process has a pH above 9. Seeing this situation, it is necessary to have a treatment unit to process boiler wastewater so that when it enters the water body receiving the discharged water has met the quality standard (pH 6-9, clear, dissolved solid value < 1500 ppm). However, the existing treatment unit has not been able to treat boiler wastewater properly so that the results of the processing are not optimal.

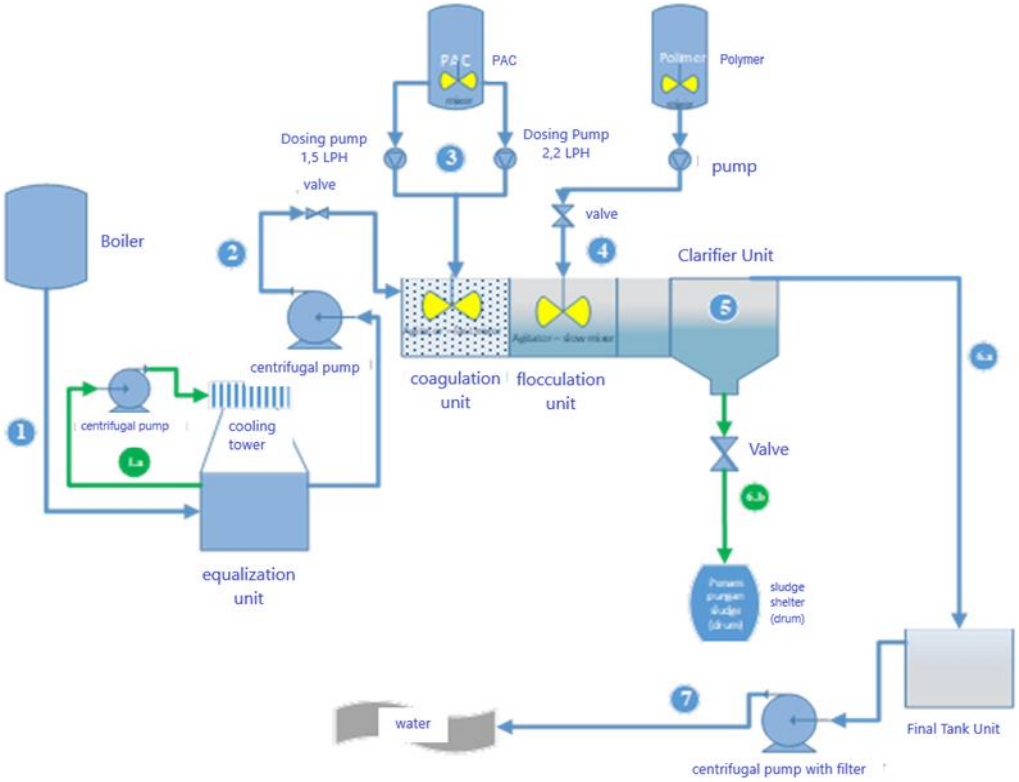

Figure 1. Work Process Flowchart

The Solution to Resolve Problems

Based on a cause-and-effect analysis of existing problems, there are methods for solving problems, namely:

- Designing an automatic control system and monitoring system using PLC as a programmable controller, Wonderware Intouch as the user interface. With the design of this system, it can be a reference to make improvements to the plant, solve existing problems, and make it easier to monitor & evaluate the situation on the ground.
- Conduct a jar test to determine the pH value with a certain reduction target so that wastewater can be processed properly.
- Design additional filter units so that the processed water can be filtered well.
- Design additional sludge storage units that can accommodate large amounts of blowdown sludge.
- Design the addition of an agitator to stir the equalization unit so that wastewater can be mixed and homogeneous.
- Design an automatic blowdown mechanism.
- Add sensors (pH, conductivity, water level) that can support the operation of the automatic control system.

The Concept

Based on the analysis of the problem, in the wastewater treatment process, there is an error in the wastewater treatment method, which results in the treatment process, not meeting the existing regulatory requirements. Against the background of these problems, the concept of WWTP was made, which can be a solution to solve existing problems and is expected to correct current process errors. The concept of the WWTP process can be seen in Figure 2.

RESULTS AND DISCUSSION

Control System Design

The design of the control system includes the design of control devices, input, and output devices on the PLC, electrical design, and specifications of the modules and devices used. Figure 3 shows the diagram block of control system design.

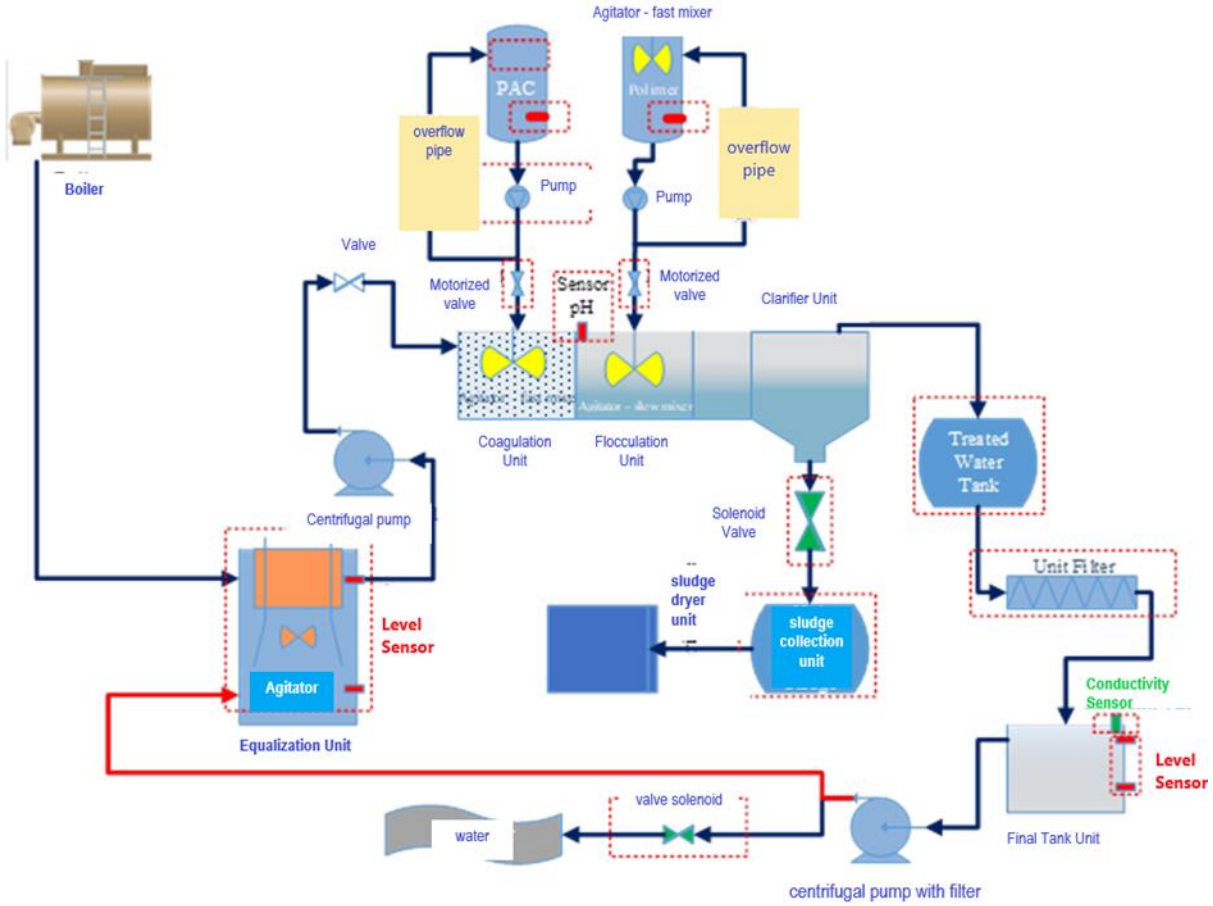

Figure 2. The concept of the Wastewater Treatment Plant

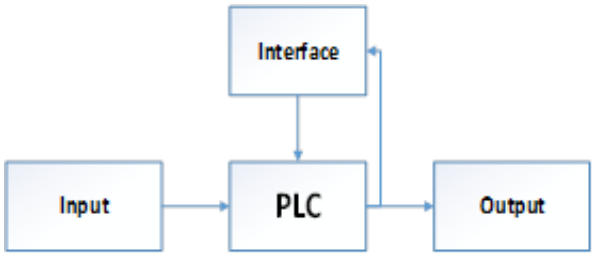

Figure 3. Diagram Block of Control System Design

Design of Control Devices and their Specifications

PLC is used as a device that controls the wastewater treatment process. In this design, PLC was chosen as a process control device because of its superior flexibility, ease of finding problems and updating, it can be monitored directly, and programming languages are easy to learn. Also, users can detect problems online by looking at the arrangement of the program. The selected PLC is a modular type PLC that allows for the addition of Input-Output modules, which are adjusted to the number of inputs and outputs from the system. The design for input devices and output devices on the PLC can be seen in Figure 4.

Figure 4 shows the number of inputs and outputs used in the design of this control system. The system uses 16 inputs and 18 outputs with details of 12 digital input devices, two analog input devices, 16 digital output devices, and two analog output devices.

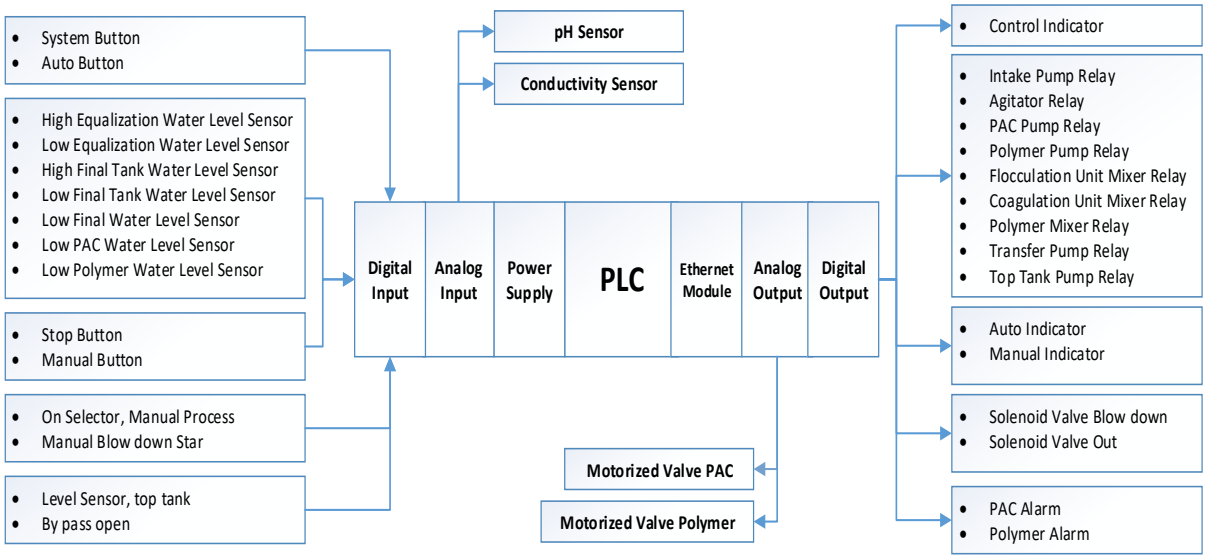

Figure 4. Input-Output Block Diagram of PLC

The control system becomes the closed-loop system

In the previous method, which is still in the form of an open-loop system where wastewater entering the holding unit will be processed by the existing wastewater treatment plant. Then the results will be discharged into drains without any feedback or other options for the disposal of the process water. This causes water that does not meet the standards (turbid and TDS > 1500 ppm) that will still be wasted into the waterways. The process control system of the wastewater treatment plant is designed by adding a conductivity sensor to the final tank unit, adding a new pipeline to the equalization unit, and adding a solenoid valve in the pipeline. So that the control system becomes a closed control system, where the incoming wastewater will be processed and reviewed by a conductivity sensor. The value of the conductivity sensor reading will be processed by the PLC and given feedback to the system whether the processed water is disposed of or not. If the reading value is in the safe number, the water will be discharged into the water channel. However, if the reading value is at a high rate, the water will flow back to the equalization unit so that the process water that is discharged into the water channel is water that meets the standards and is free of hazardous and toxic material content.

Program Design and Configuration

PLC configuration

This wastewater treatment system uses PLC as its control device. The PLC used is a PLC with a modular type, so it must be configured in advance so that the CPU and modules installed on the base unit can be connected so that the sequence of programs can run accordingly.

PLC configuration with the interface

The wastewater treatment system can also be monitored and controlled through an interface. The interface used is Wonderware Intouch.

Flow chart

WWTP operation for the wastewater treatment process will be programmed using PLC as the control device. There are two methods in the process of treating waste in the system. Figure 5 shows the program for auto mode, while the whole program is attached.

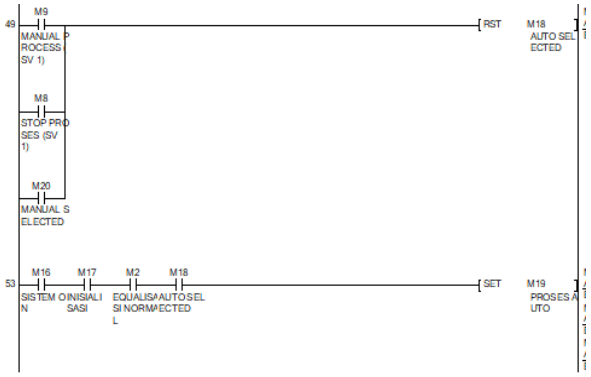

Figure 5. A part of the Wastewater Treatment System Program

The first method is to use an auto mode which parameter settings and activation of the supporting system of the system is carried out in full by the program sequence by utilizing the input values of the input devices (sensors, selector switches, pushbuttons) connected to the PLC so that the system can run without manual input performed by the operator. While the operation of the plant with the second method is manual mode, the operator must activate the system supporting

devices manually and set its parameters so that the system can treat waste properly.

Interface Design

The interface is used as a monitoring tool and a remote-control tool. The interface that the author made uses four windows, namely the login window, the menu window, the windowpane, and the plant monitoring window. This interface uses a special security system so to open a panel or monitoring window. You must log in first. The menu window is used to select the window you want to open after logging in. The windowpane is used to monitor and control the process (manual mode). The plant monitoring window can only be used to view inputs-outputs and parameters that are currently running.

Figure 6 shows the menu window for selecting which window to open. In this window, there are three-word buttons, namely the main panel button to display the main panel window, the plant button to display the plant window, and then log out button to return to the login window.

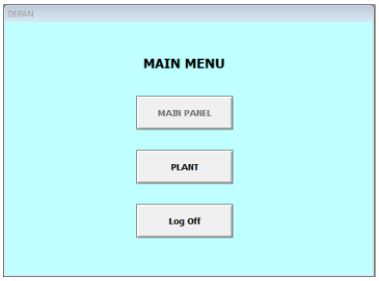

Figure 6. The Menu Window

Figure 7 shows the display from the main panel window. The main panel window can only be accessed by users with high-level access, namely Administrators and operators. Meanwhile, if the login is a guest, then the main panel button will not be selected. In the main panel window, the user and operator can monitor and run the system by activating the buttons on the window and can adjust motorized valve opening values when in manual mode.

In the main panel window, there is a main control tab that functions to activate and stop the system and choose the system mode, the actuator tab to display the actuator (pump, solenoid valve) which is active, the analog value tab to display the analog value, the manual activation tab to activate the pump in manual mode, the shelter unit tab to display the shelter level and the manual control tab to activate the manual process when manual mode is selected.

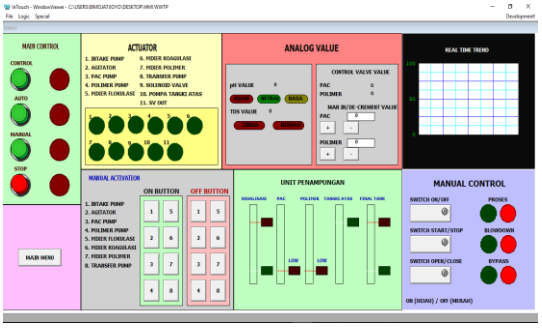

Figure 7. Main Panel Window

Figure 8 shows the display for the plant window. This window is intended for all levels of access from administrators, operators, and guest users or visitors. This window is only used for monitoring plants but cannot be used to run systems such as the main panel window.

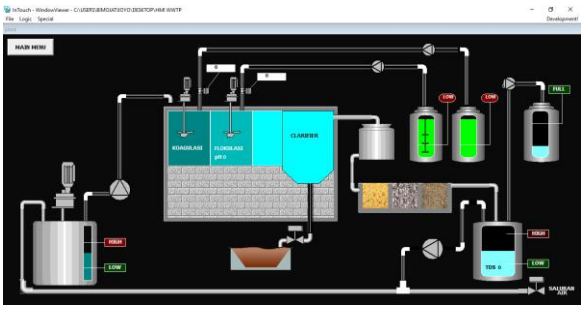

Figure 8. Monitoring Window

Testing

Testing on the system can be done by monitoring the Personal Computer or by looking at the indicators (pilot lamp) that are on the control panel. In addition to testing the system, testing of work processes must also be carried out to match field conditions with the system.

Input-Output Testing at Interface

Testing input and output devices can be done through an interface on a Personal Computer (PC). The interface is created using Wonderware Intouch software. The interface created is not only used to view or read contacts or active instructions (the read function) but can also give commands directly from the interface to the PLC system (Write function).

Work Process Testing

Testing on the process can be done by monitoring through the output movement or status LEDs that are on the PLC, indicators on the interface, and indicator lights from the control panel. Following is a table that shows how to test the wastewater treatment system to check the function of each output device connected to the PLC.

Discussion about Design Evaluation

The design evaluation that it makes is a theoretical estimate of the results to be obtained if the process control system is applied to the wastewater treatment plant. Estimated results to be obtained can be seen from several aspects, namely: reduction of operator workload, quality of processed wastewater products can always be monitored to comply with government regulations, process consistency, safety, and the systems become a closed loop.

Quality of water

The design of the process control system for wastewater treatment uses a pH sensor as a detector for the pH value of the flocculation unit. Whereas the conductivity sensor as a detector of conductivity values in water will then be programmed so that the conductivity values that are read can be converted to TDS values. The values from the sensor readings will be displayed on the interface created using the Wonderware Intouch software. As well as the values of the sensor readings will be a parameter to determine the size of the motorized control valve opening and whether the solenoid valve bypass is used as a programmatic opening and closing device.

The existence of sensors, solenoid valves, control valves (motorized valves), and interfaces in the system can ensure that wastewater treatment can run well programmed and can be monitored directly without having to check manually in the field.

So that the quality of wastewater from the process results can meet government regulations, namely, the value of process water is at pH 6-9, the sludge is separated from the water so that the water becomes clear, the water discharged into the water channel < 1500 ppm. If water is > 1500 ppm, it will flow back to the equalization unit. With the interface, the user can monitor the state of the plant directly so that when there are problems or abnormal circumstances, the user will immediately know and can plan and take corrective actions quickly.

Process consistency

In the previous method of operation, there were many problems, including the different operators' understanding of the waste treatment process. This causes the treatment to be inconsistent so that new problems arise, such as processed water that still does not meet the standards. Also, there was an overflow of wastewater in the holding unit because it was not processed and flooded at the WWTP. The wastewater treatment system that is designed using PLC as a programmed control can overcome inconsistent wastewater treatment.

The PLC to be used has been programmed by following the flowchart that has been made based on standard operating procedures and works instructions so that wastewater treatment can run consistently and stable by following the sequence of programs made. This can avoid errors that occur due to differences in understanding the operation of the plant by the operator.

CONCLUSION

This paper has discussed the design of control systems and monitoring systems in wastewater treatment plants in an automotive manufacturing company. These control and monitoring wastewater treatment systems use a modular type PLC as a device to control the course of the wastewater treatment process. The modular PLC used for this design consists of a Q61P type power supply, QX40 digital input module, QY10 digital output module, Q64AD analog input module, and Q64DAN analog output module. The number of input and output devices connected to the PLC are 14 discrete input devices, 16 discrete output devices, three analog input devices, and two analog output devices. PLC is used because it considers the device durability, ease of programming, and problem detection. Display interface created using the Wonderware Intouch software. This is because many features that allow for a more attractive appearance than HMI software in general. The interface display is divided into four pages, namely: the login page to authenticate the user's identity, the main menu page as the main page, the main page as the control panel page for reading and giving commands to the PLC, and the plant page that is devoted solely to monitoring plant conditions, i.e., normal or abnormal.

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